LSST Next-gen

Christopher Stubbs
Harvard University
September 2015

Context

- LSST v1.0 is a multiband imaging survey of the Southern sky in *ugrizy* bands
- Primary DOE community interest is dark energy, but the measurements also will bear upon the dark matter problem, and the sum of neutrino masses.
- Initial vision is a 10-year survey of the entire accessible Southern sky, combining time domain information (frame subtraction) and deep imaging (co-addition of images).
- We will have made a billion dollar investment in captial and operating costs, with sophisticated hardware & software
- OK, then what?

LSST v2.0 Options

1. Execute a different survey strategy, with same instrument and analysis software

2. Implement a different filter set.

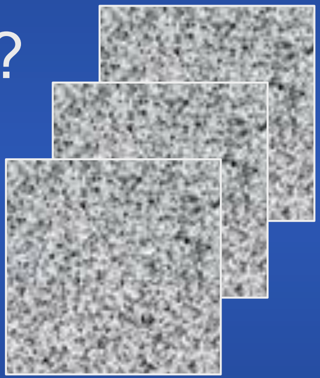
3. Build a multi-object robotic spectrograph across the 10 square degree field.

4. Change from CCDs to infrared detectors (out to 2 microns).

5. Change from CCDs to energy-sensitive sensors (MKIDS talk)

Option 1: Different survey strategy, same instrument

- It would be simple to alter the observing strategy, with the original focal plane, filter set, and analysis software.
- Deeper imaging of a sub-area on the sky?
- Time domain coverage of
  - microlensing
  - supernovae
  - time delays in strongly lensed systems
  - gravitational wave sources
  - …
- This amounts to changing the spatio-temporal coverage.



Option 2: Implement a different filter set

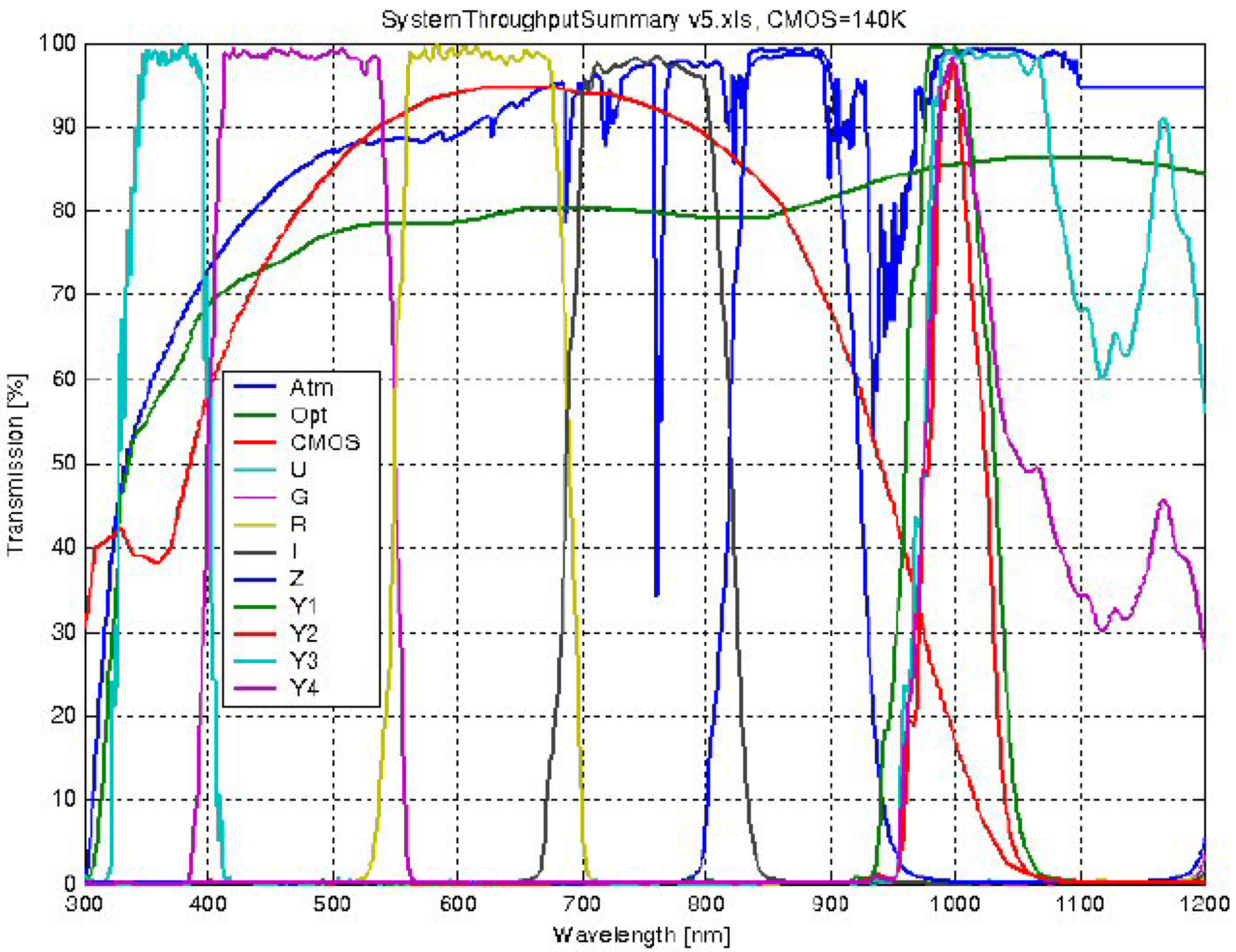


Figure 3. Baseline LSST Optical transmission (Air Mass=1.0)

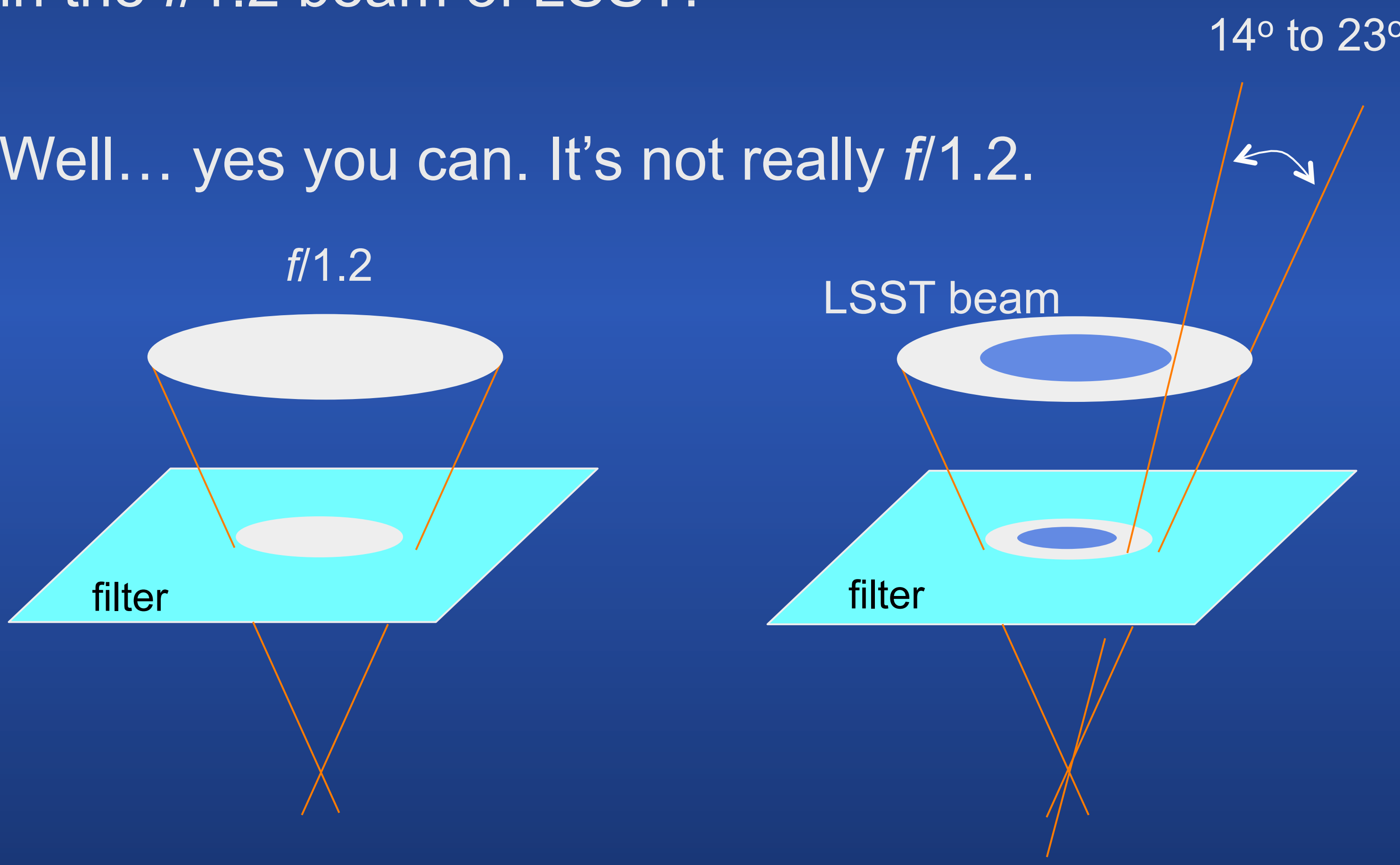
Option 2: Implement a different filter set

- Augment the filter set with different/narrower passbands for
  - improved photo-z's (LSS and dark energy, neutrino mass)
  - better stellar classification (Galactic structure, MW DM)
  - cluster membership selection
  - Photometric BAO
  - Large scale structure survey with emission line galaxies
  - Improved Galactic extinction corrections
  - …

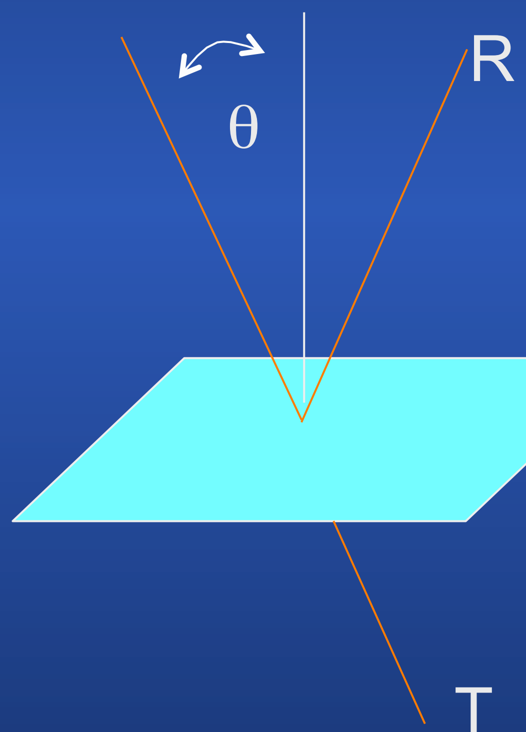
Narrowband filters?

- “But wait, you can’t put narrowband interference filters in the *f*/1.2 beam of LSST!”

- Well… yes you can. It’s not really *f*/1.2.



Transmission shift with angle of incidence depends on effective index of the filter material



$$\lambda(\theta) = \lambda_o \sqrt{1 - ((\sin\theta)/n_{eff})^2}$$

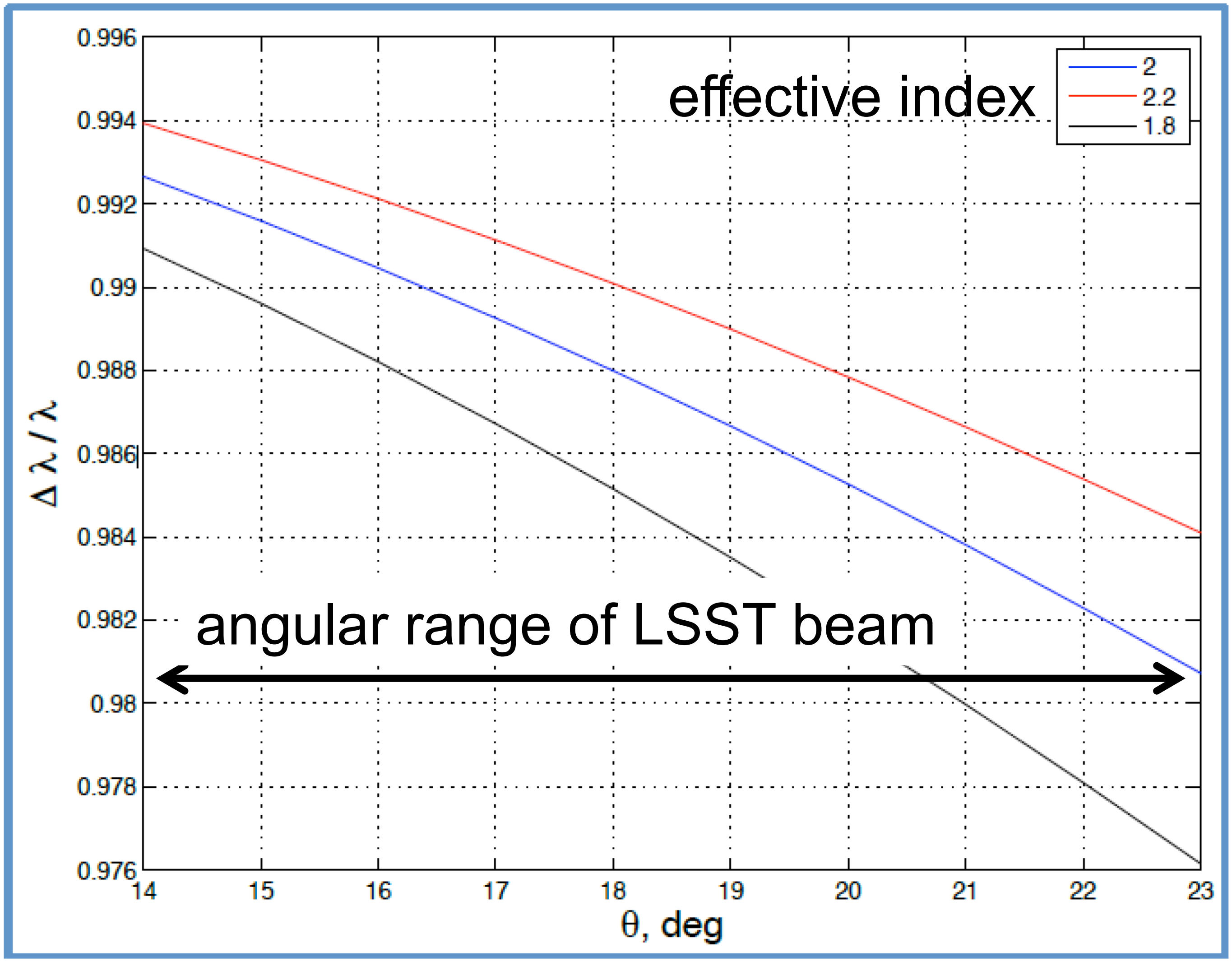


Figure 1. Incidence angle dependence of wavelength shift. The horizontal axis spans the range of angles of incidence in the LSST beam. The vertical axis shows the fractional change in wavelength, compared to θ=0, for the effective index values of 1.8, 2.0 and 2.2.

It seems to me we can use filters that are 20 nm wide, as opposed to 100 nm

- With Silicon CCDs the useful range of wavelengths is limited to:

  λ > 350 nm due to atmospheric cutoff
  λ<1000 nm due to silicon bandgap
  so $\Delta\lambda$ ~650 nm.

- We span this with 6 (ugrizy) bands, each about 100 nm wide
- At Dl ~ 20 nm we would use ~32 bands
- A single narrowband filter likely costs around 500K$.
- Covering the entire range would cost ~ 16M$.

Table I. Potential Narrowband Filter Choices and Applications.

Central wavelength (A)	Galactic structure and stars	Ly-α 1215A redshift (quasars)	Hα+NII 6563/6548/6583A redshift (large scale structure)	[OIII] 4959/5007A redshift (PNLF distances)
3900	Stellar metallicity	2.2	NA	NA
5007	PNe, SN remnants	3.1	NA	To 50 Mpc, typically
7780	Stellar TiO	5.4	0.18	NA
8210	Stellar CN	5.7	0.25	NA
6563	H-α map	4.4	0.0	NA
10000	L dwarf classification	7.2	0.53	NA

from "Narrowband Filter Considerations for LSST', C. Stubbs, April 2015

Option 3: Wide-field spectroscopy

- Replace the imager at the focus of LSST with a robotic fiber optic positioner, and use the LSST sensors and electronics as elements in spectrograph cameras, one per raft.
- The range of incident beam angles is too wide to efficiently couple into an optical fiber, we need to do something about that
- We can re-image the beam to put pupil image onto fiber tips

Option 3: Wide-field spectroscopy (DESILSST)

- The DESI team is developing robotic fiber positioners
- At 700 fibers per square degree (DESI density) the LSST field would accommodate ~7000 fibers.
- I don’t know how much it would cost to do this, considerations include
  - light loss in long fiber runs
  - lack of an atmospheric dispersion corrector. Do we add one?
  - what is the marginal gain from doing a Southern hemisphere deep redshift survey?
- Maybe supplement the LSST CCDs with infrared devices, to obtain spectra that span from 350 nm to 2 microns?

Option 4: NIR focal plane

- We could pave the LSST focal plane with infrared sensors, and extend the wavelength coverage by a factor of two, from red limit of 1 micron to ~2 microns.
- IR sensors are currently much more expensive than Silicon, per square mm of imaging area.
- This would likely require breaking the cost curve for NIR imagers, in order to be affordable

Option 5: Use novel sensor technology

- A major limitation of Si CCDs is lack of energy sensitivity. We get one photoelectron per incident photon.
- We could envision paving the LSST focal plane with energy-sensitive sensors, getting spectral resolution in an imaging system.
- MKIDS?
- other?